



The Forte Framework for Music Composition

Jakub Korczyński
Lambda Days 2015



„Now art is the contrary of chaos.”

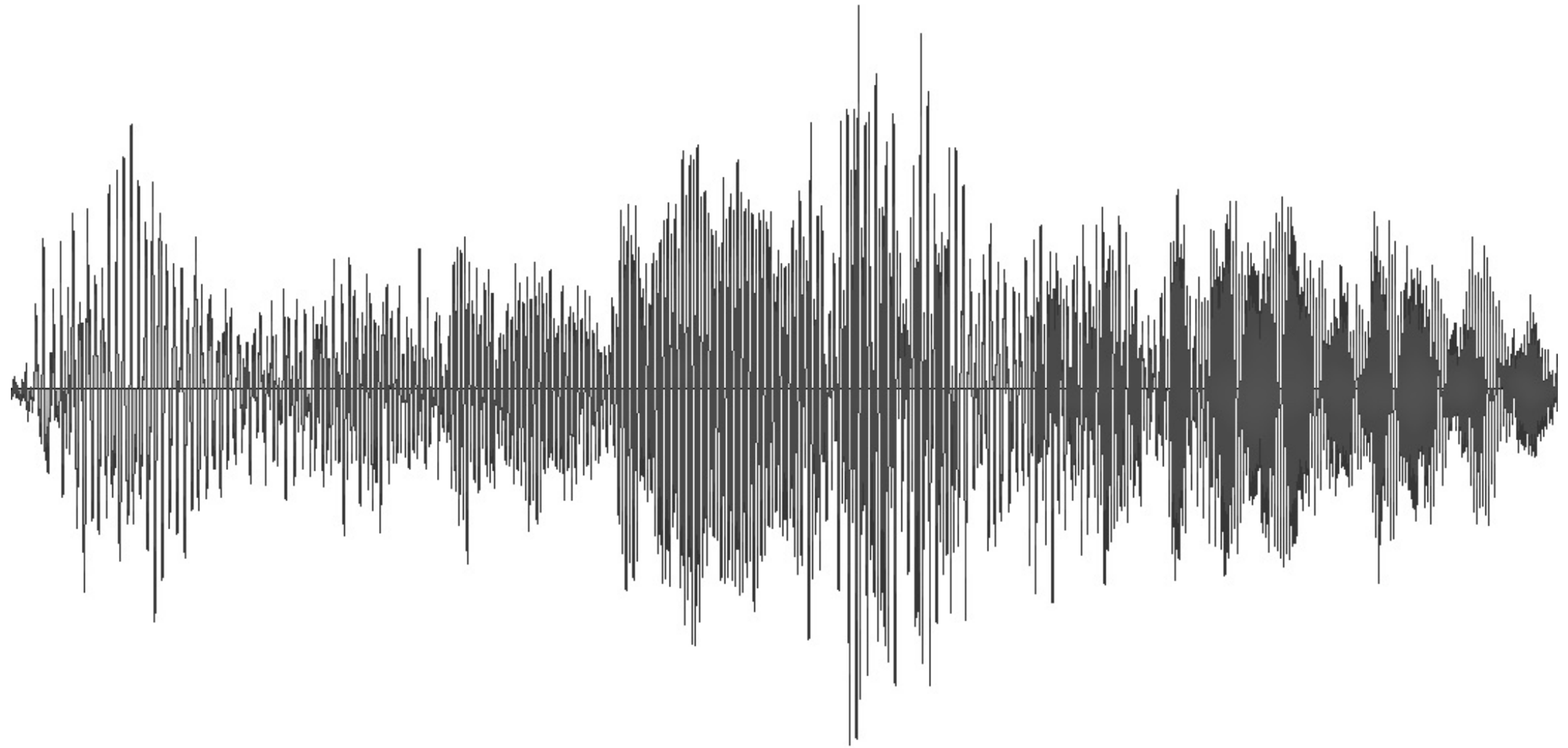
– Igor Stravinsky

The Problem



Frederic Chopin playing for prince Radziwiłł in 1887,
Henryk Siemiradzki

How to grasp music?



"Etude in A minor" (Op. 10, No. 2) by Fryderyk Chopin

A partial solution

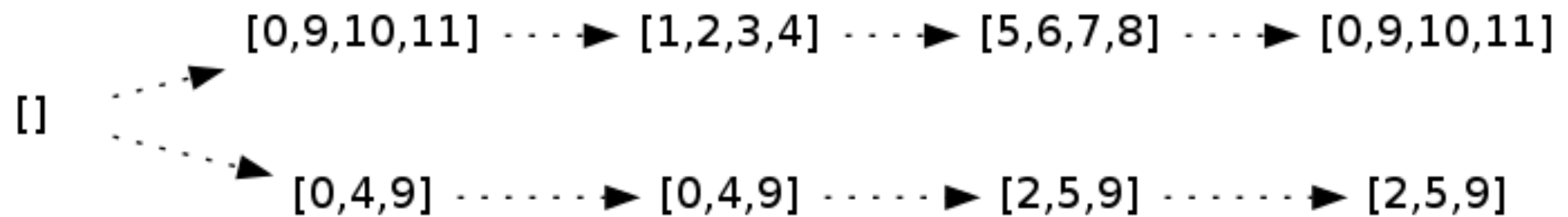
Allegro. (♩ = 144.)
sempre legato

2. *p* *cresc.*

The image displays a musical score for the second system of Chopin's 'Etude in A minor' (Op. 10, No. 2). The tempo is marked 'Allegro' with a quarter note equal to 144 beats per minute. The instruction 'sempre legato' is present. The score is in A minor, 4/4 time. The first system begins with a piano (p) dynamic and a crescendo (cresc.) marking. The second system continues the intricate fingerings and includes a decrescendo marking. The score is written for two staves, with the right hand playing a complex chromatic pattern and the left hand providing a steady accompaniment.

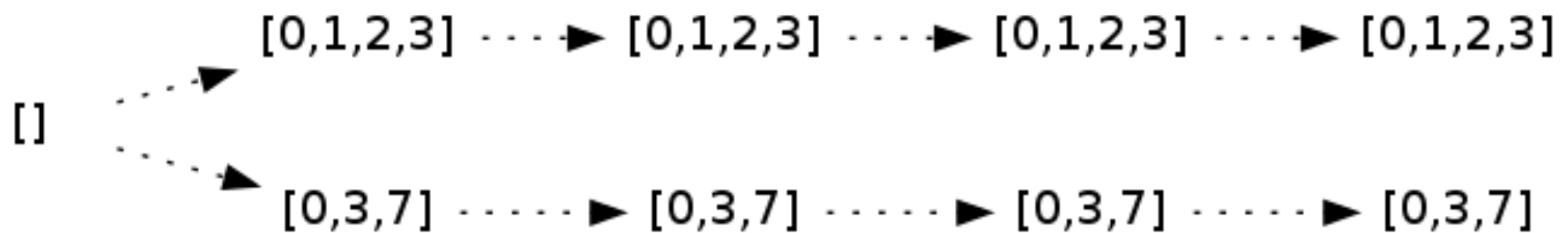
"Etude in A minor" (Op. 10, No. 2) by Fryderyk Chopin

What we would like instead?



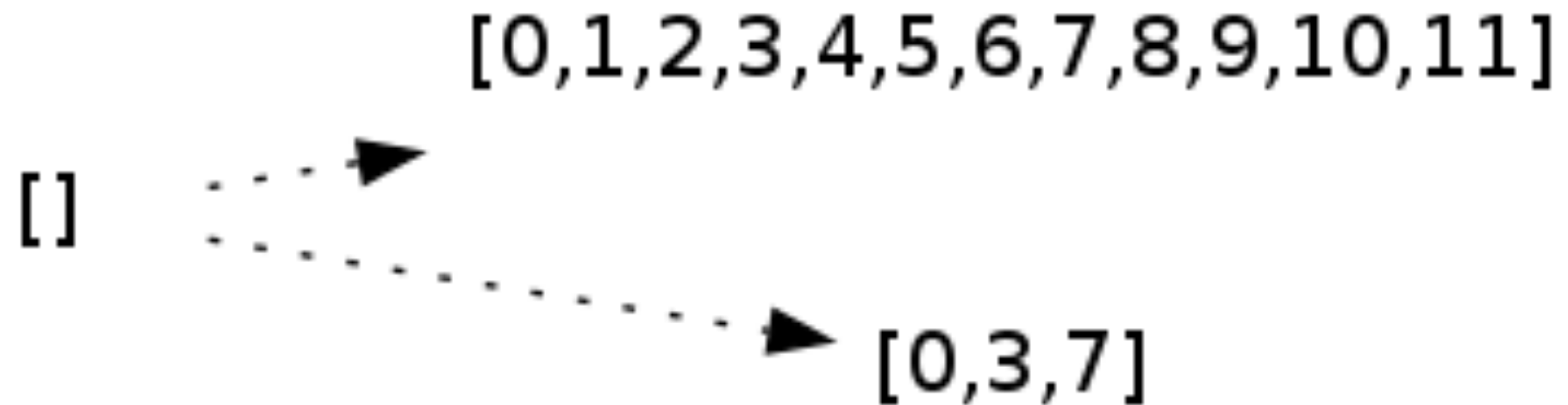
"Etude in A minor" (Op. 10, No. 2) by Fryderyk Chopin

Even better ...



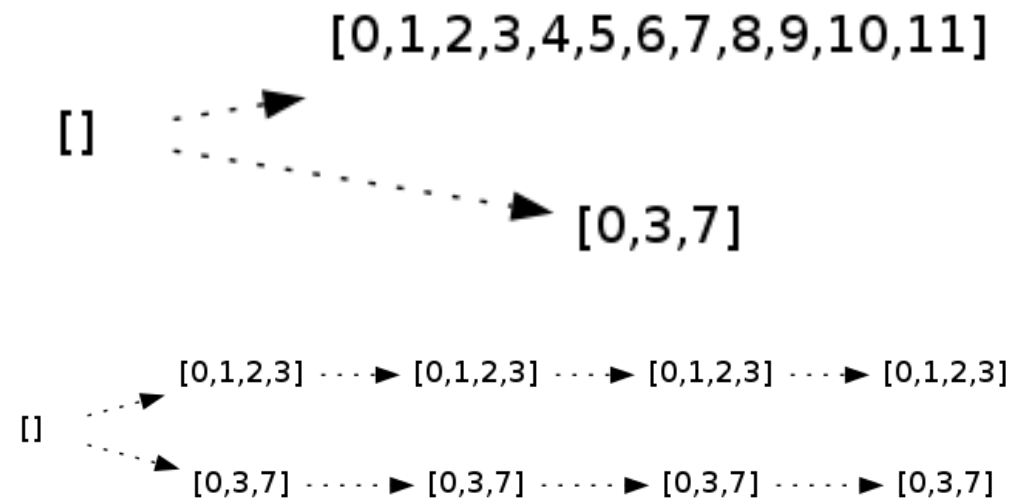
"Etude in A minor" (Op. 10, No. 2) by Fryderyk Chopin

Wow!



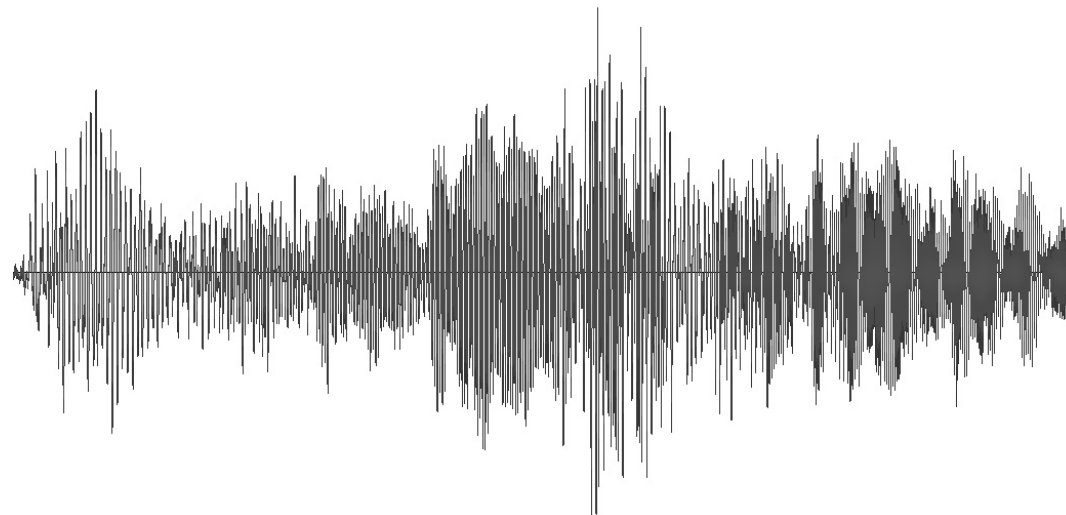
"Etude in A minor" (Op. 10, No. 2) by Fryderyk Chopin

Structure Theory



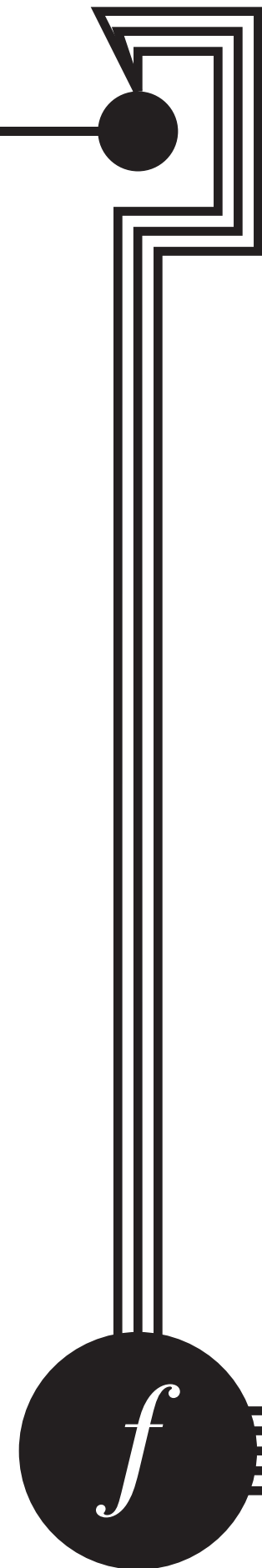
Allegro. ($\text{♩} = 144$)
sempre legato

2. *p* *cresc.*





*f*ORTE



Forte DSL

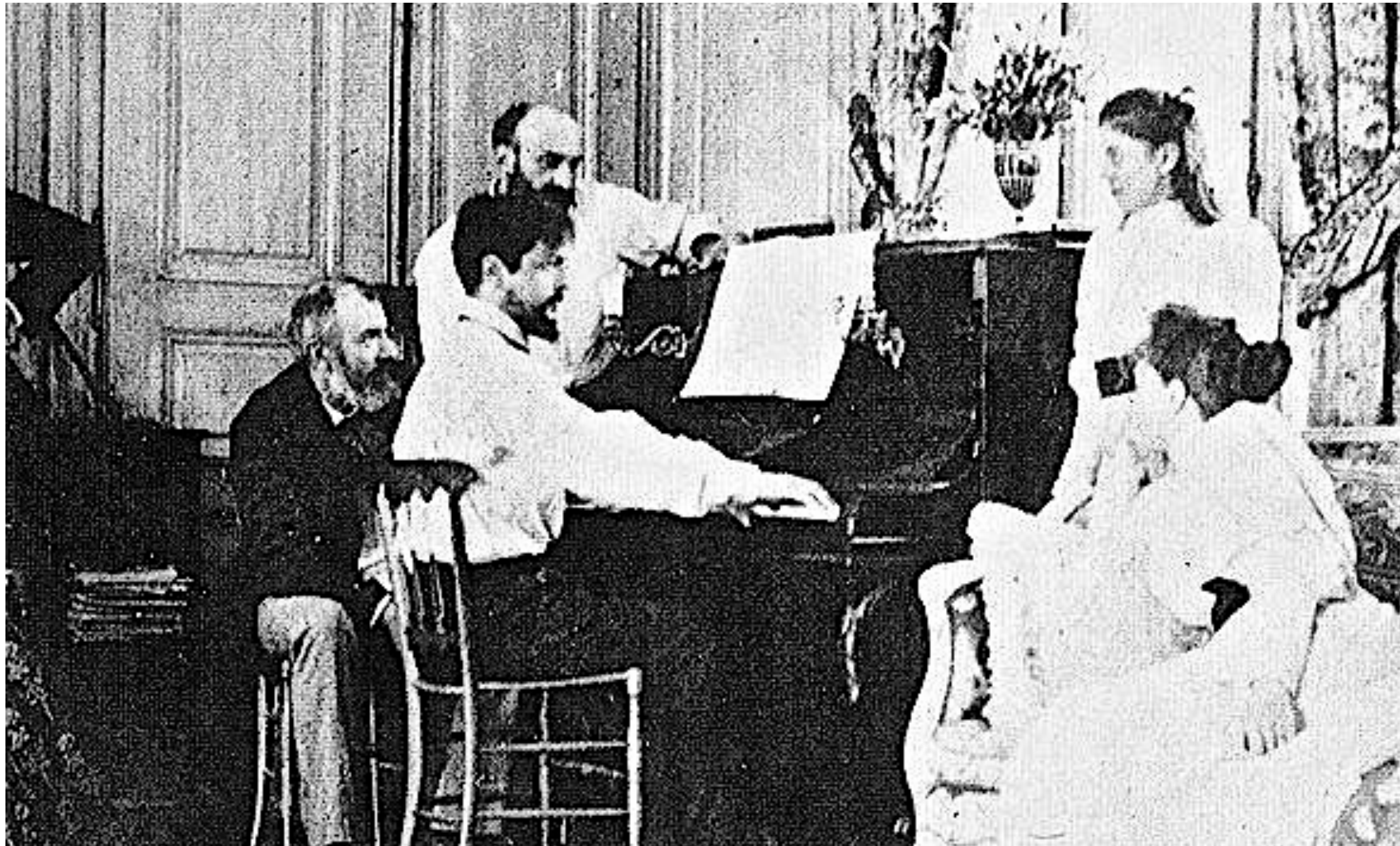
Forte DSL

Allen Forte (born December 23, 1926) is a music theoretician and musicologist best known for his work “The Structure of Atonal Music” published by Yale University Press.

What is Forte theory?

- A mapping of pitches to pitch classes
- A mapping of intervals to interval classes
- A grouping of pitch classes with pitch class sets
- Pitch class set normalization
- Various pitch class set relations
- Analysis with interval vectors and basic interval patterns
- Complexes and subcomplexes

Mapping music to numbers



Claude Debussy at the piano

Pitches to Pitch Class Sets

Andante très expressif

The musical score is for the first system of 'Clair de lune' by Debussy. It is in G-flat major (three flats) and 9/8 time. The tempo/mood is 'Andante très expressif'. The score consists of two staves. The right staff begins with a treble clef, key signature of three flats, and a 9/8 time signature. It contains a quarter rest followed by a dotted quarter note G4, which is part of a larger melodic phrase. The left staff begins with a bass clef, the same key signature, and time signature. It contains a quarter rest followed by a dotted quarter note G3. The dynamic marking 'pp' (pianissimo) is placed between the staves. The phrase 'con sordina' (with mutes) is written below the left staff. The score shows a forte mapping from the pitch class set [0,3,7] (G3, Bb3, D4) to [0,3,6,9] (G3, Bb3, D4, F4).

pp

con sordina

=

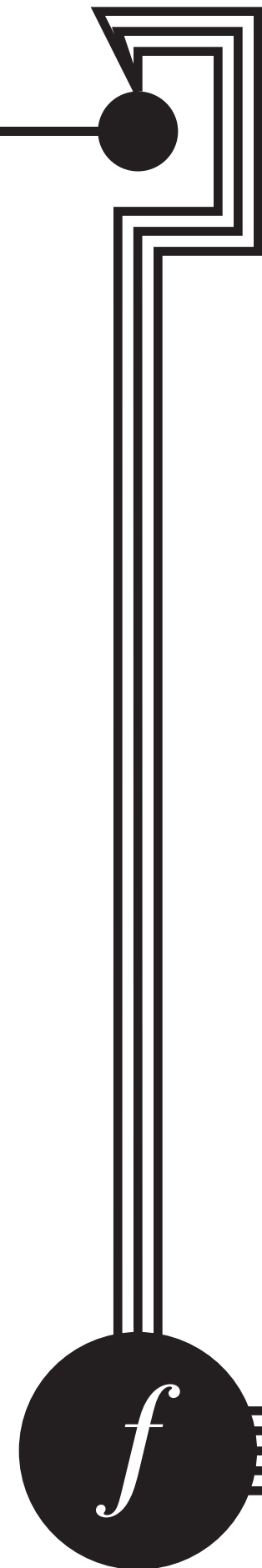
[0,3,7] . . . ➔ [0,3,6,9]

Forte mapping - "Clair de lune" C. Debussy

Contributions

What we propose:

- Forte theory systematization and enhancement
- A EDSL instead of a batch processor for manipulating
- Forte-theoretic entities
- Techniques for domain abstraction, interpretation swapping and self-optimizing library implementation
- A method for boilerplate code reduction



Graph DSL

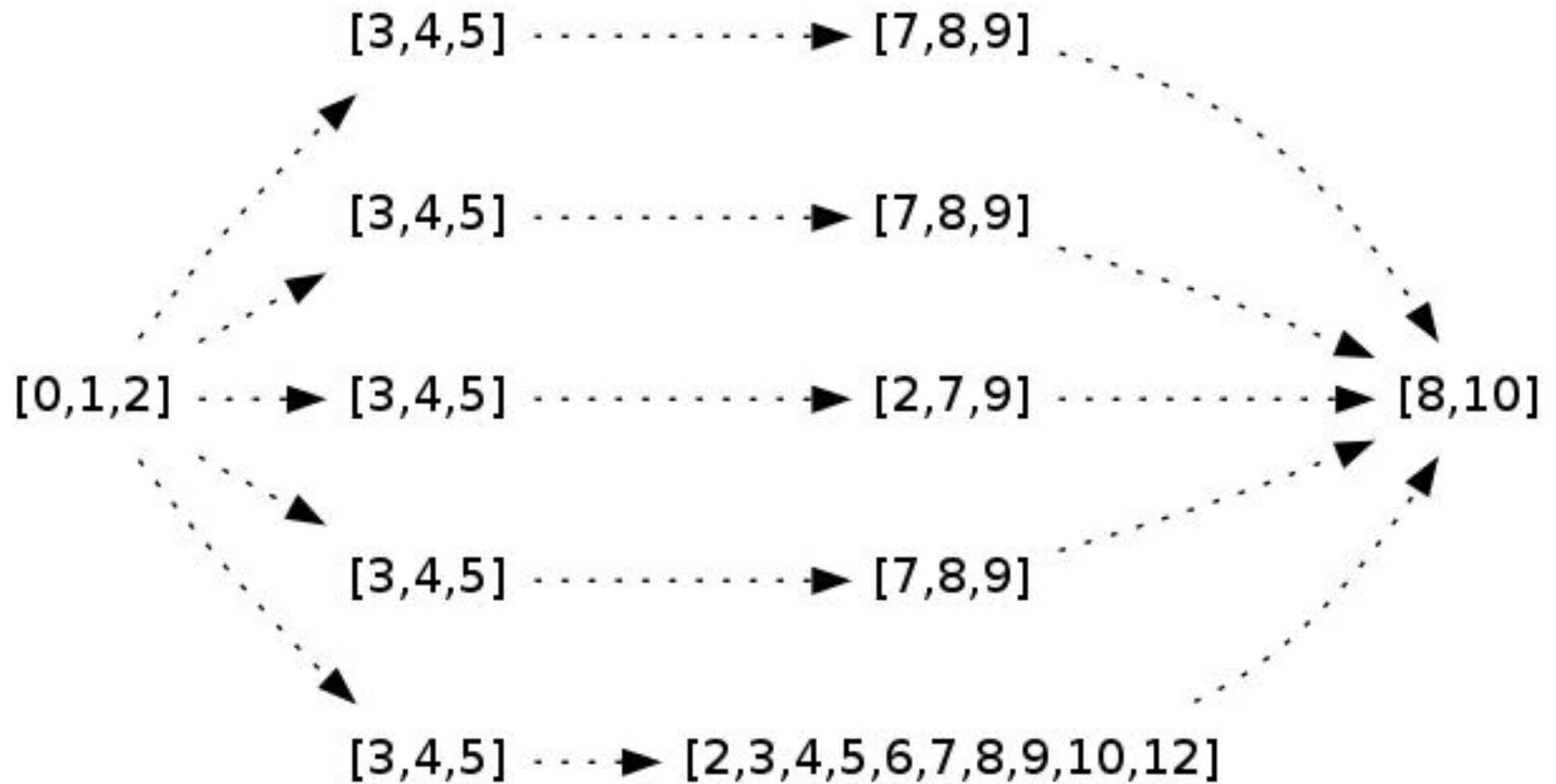


Graph DSL

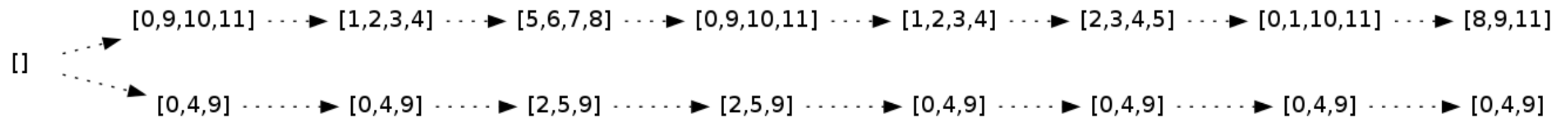
Basic concepts:

- Modeling music as a graph
- Time axis and musical time windows
- Vertical plane
- Musical paths and the horizontal plane

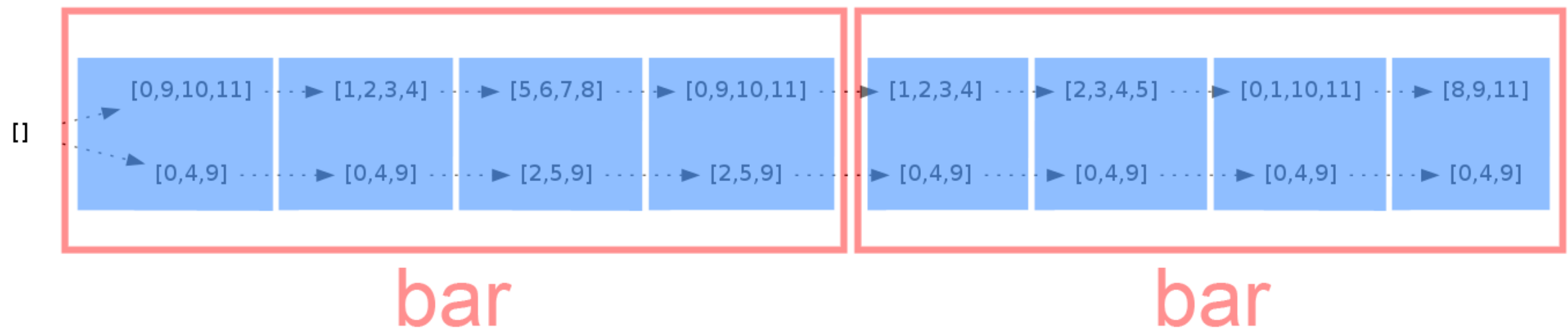
Graph DSL example



Musical Time Window



Musical Time Window



Musical Time Window

Musical Time Window

The diagram illustrates a musical score with two measures highlighted in blue, each labeled "bar" in red text below. The first measure is further labeled "quarter" in blue text above it. The score is written for piano (p) and includes the tempo marking "Allegro. (♩ = 144.)" and the instruction "sempre legato". The first measure contains a piano part with a crescendo (cresc.) and a treble part with a sequence of notes and fingerings (4, 3, 4, 5, 3, 4, 3, 4, 5, 3, 4, 3, 4, 5, 3, 4, 3, 4, 5). The second measure contains a piano part with a sequence of notes and fingerings (3, 4, 3, 4, 5, 4, 3, 4, 3, 5, 4, 3, 4, 3, 5, 4) and a treble part with a sequence of notes and fingerings (3, 4, 3, 4, 5, 4, 3, 4, 3, 5, 4, 3, 4, 3, 5, 4). The diagram shows how a single musical phrase can span across multiple measures, illustrating the concept of a "Musical Time Window".

Allegro. (♩ = 144.)
sempre legato

p

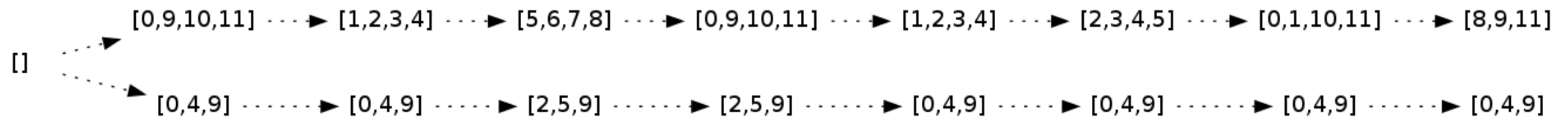
cresc.

quarter

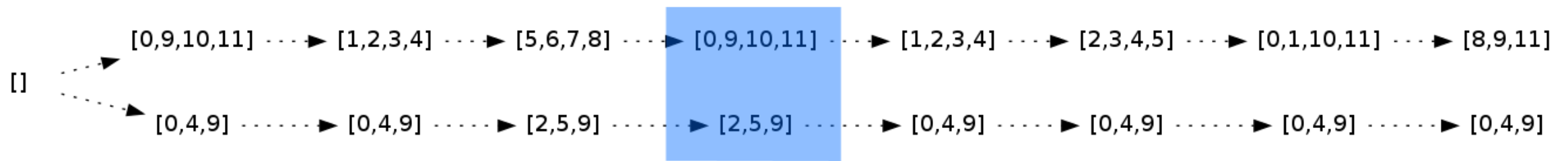
bar

bar

Vertical Plane



Vertical Plane



Vertical Plane

Allegro. (♩ = 144.)
sempre legato

The musical score is written for piano in common time (C). The tempo is marked 'Allegro.' with a quarter note equal to 144 beats per minute. The instruction 'sempre legato' is written above the staff. The piece begins with a piano (p) dynamic. The right hand features a complex melodic line with many triplets and slurs, while the left hand provides a rhythmic accompaniment with chords and single notes. A 'cresc.' (crescendo) marking is placed between the first and second measures. The score is divided into two systems by a double bar line. The second system includes a hairpin crescendo symbol. The key signature has one sharp (F#), and the time signature is common time (C). Fingerings are indicated by numbers 1-5 above or below notes. The piece concludes with a final chord in the right hand and a sustained note in the left hand.

p *cresc.*

Vertical Plane

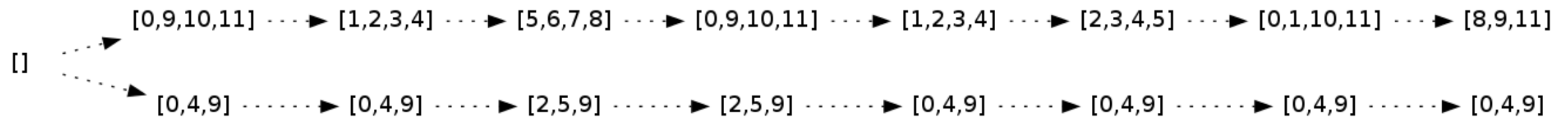
Allegro. (♩ = 144.)
sempre legato

The image displays a musical score for piano, featuring a treble and bass staff. The tempo is marked 'Allegro. (♩ = 144.)' and the performance instruction is 'sempre legato'. The score includes various musical notations such as notes, rests, and fingerings. A blue shaded region highlights a specific section of the music, labeled 'Quarter Note Time Window'. This region is defined by a vertical line and a blue background. The notation within this window shows a sequence of notes and rests, with fingerings indicated above and below the notes. The score also includes dynamic markings like 'p' (piano) and 'cresc.' (crescendo). The bass staff has a '5' written below the first note, and the treble staff has a '4' written above the first note. The score is written in common time (C) and features a key signature of one sharp (F#).

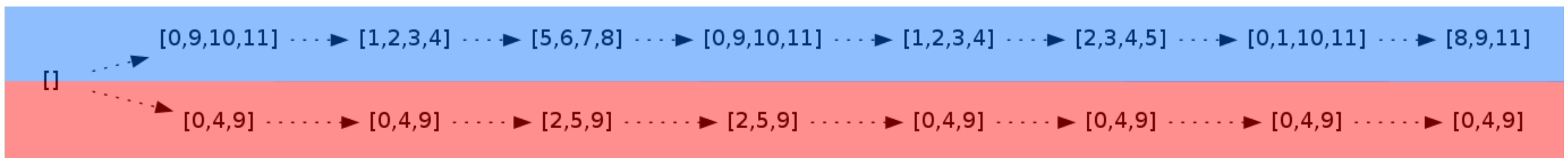
p *cresc.*

Quarter Note Time Window

Horizontal Plane



Horizontal Plane



Horizontal Plane

Allegro. (♩ = 144.)
sempre legato

The musical score is written for piano in common time (C). The tempo is marked 'Allegro.' with a quarter note equal to 144 beats per minute. The instruction 'sempre legato' is written above the staff. The piece begins with a piano (p) dynamic. The right hand features a complex melodic line with many triplets and sixteenth notes, while the left hand provides a rhythmic accompaniment with eighth and sixteenth notes. A 'cresc.' (crescendo) marking is placed between the first and second measures. The score is divided into two systems by a double bar line. The second system includes a hairpin crescendo symbol spanning across it. The piece concludes with a final chord in the right hand and a sustained note in the left hand.

p *cresc.*

Horizontal Plane

Allegro. (♩ = 144.)
sempre legato

The image shows a musical score for piano and violin. The piano part is in the lower register, with a red background. The violin part is in the upper register, with a blue background. The piano part features a series of chords and single notes, with a crescendo marking. The violin part features a series of sixteenth-note runs, with a crescendo marking. The two parts are separated by a horizontal line, illustrating two distinct horizontal planes.

p *cresc.*

Two Horizontal Planes



Graph DSL operations



Function application code example

```
forte [pcs [0, 1, 2], pcs [2, 3, 5]] $  
  init  
  $=: transpose 5  
  $=| [2] |= primeForm
```


Function Application Intuition

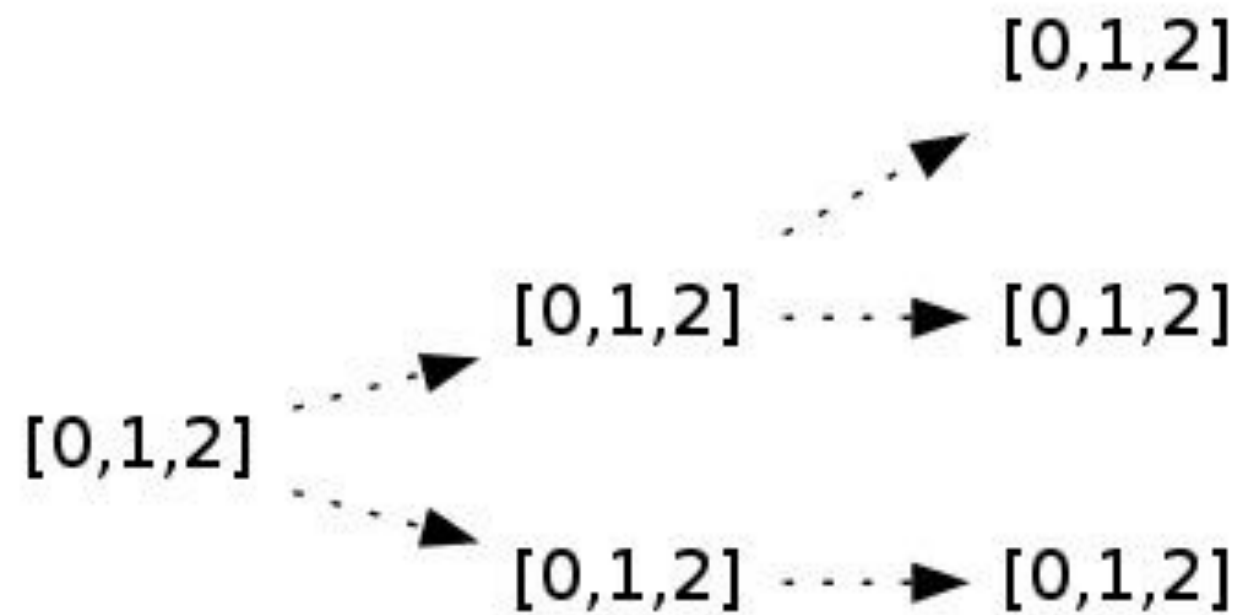
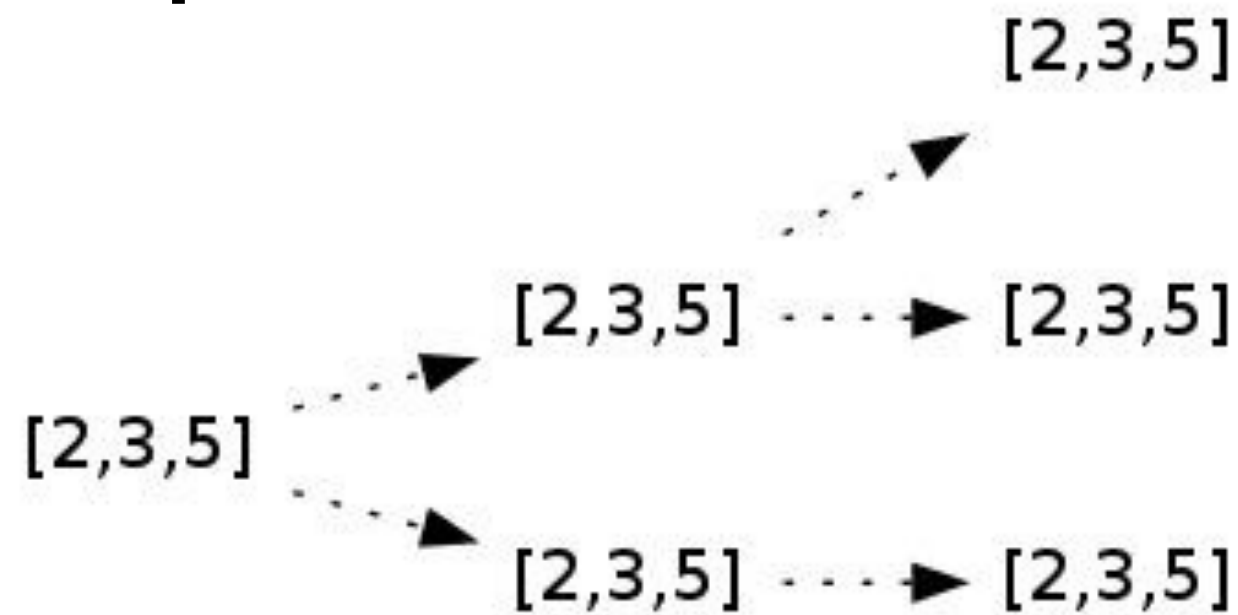
$[2,3,5] \dashrightarrow [7,8,10] \dashrightarrow [0,1,3]$

$[0,1,2] \dashrightarrow [5,6,7] \dashrightarrow [5,6,7]$

Split code example

```
forte [pcs [0, 1, 2], pcs [2, 3, 5]] $  
  init  
  $<: 2  
  $<| [1, 3] |< 2
```

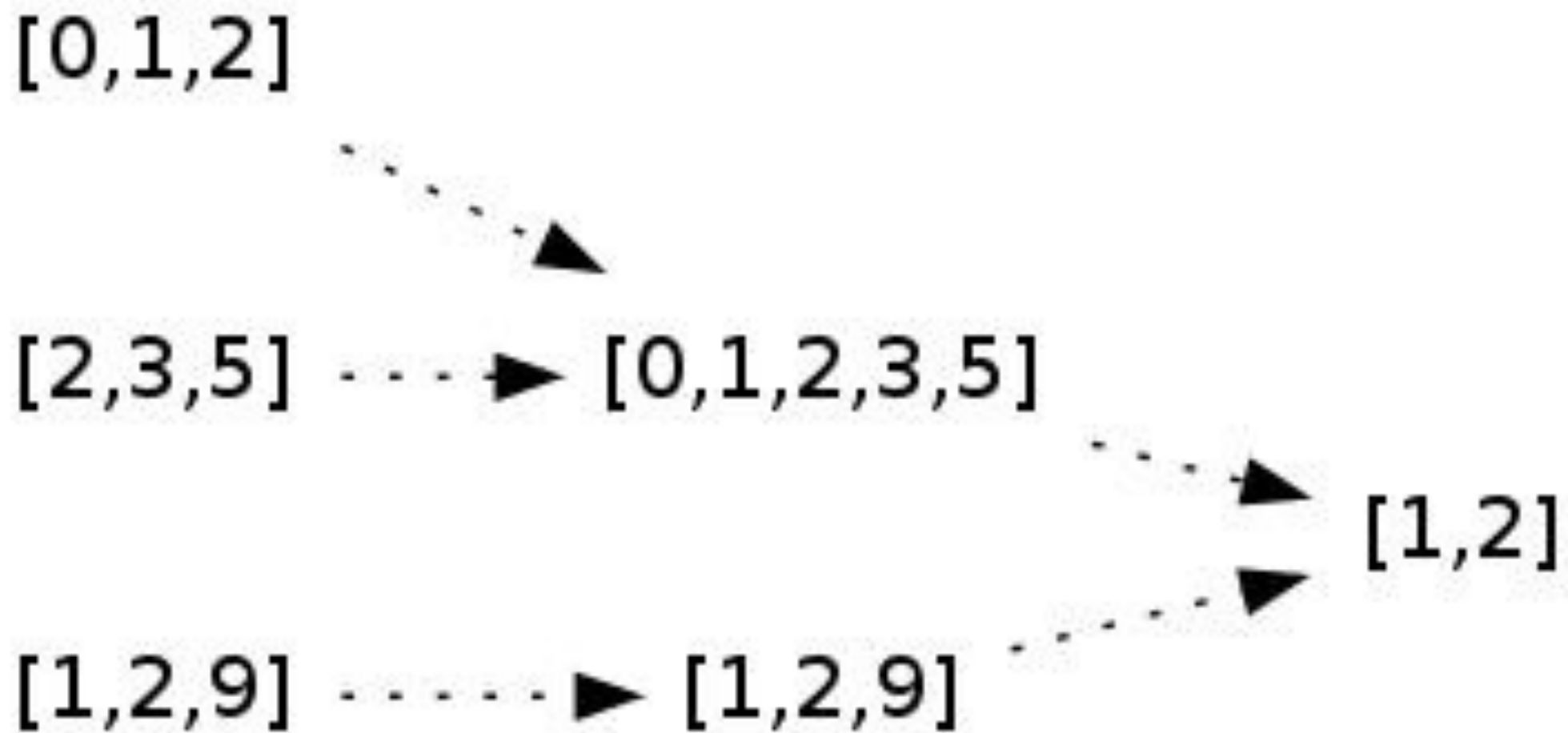
Split intuition



Merge code example

```
forte [pcs [0, 1, 2], pcs [2, 3, 5], pcs [1, 2, 9]] $  
  init  
  $>| [1, 2] |> unify  
  $>: intersect
```

Merge Intuition



Cut and Inject code example

```
forte [pcs [0, 1, 2], pcs [2, 3, 5], pcs [1, 2, 9]] $  
  init  
  $>> 1  
  —| [2..]  
  +: pcs [5, 6, 7]
```

Cut and Inject Intuition

$[1,2,9] \dashrightarrow [1,2,9]$

$[2,3,5] \dashrightarrow [2,3,5]$

$[0,1,2] \dashrightarrow [0,1,2] \dashrightarrow [5,6,7]$

Helper code example

```
forte [pcs [0, 1, 2]] $
```

```
init
```

```
$<=: (5, transpose 3)
```

```
=| [1] |= multiply 11
```

```
=| [2] |= transpose 4
```

```
=| [3] |= transpose 6 . multiply 5
```

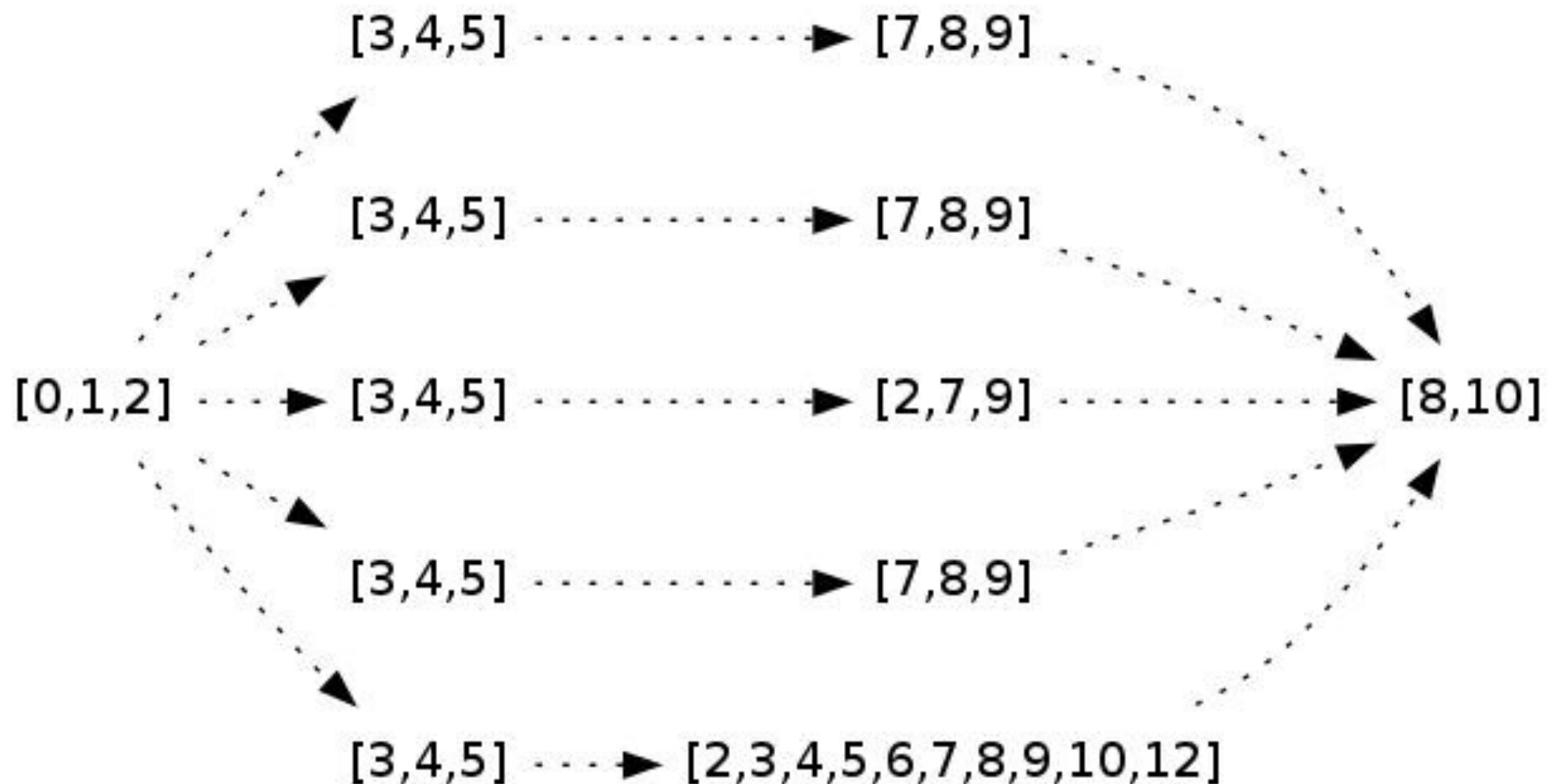
```
=| [4] |= invert
```

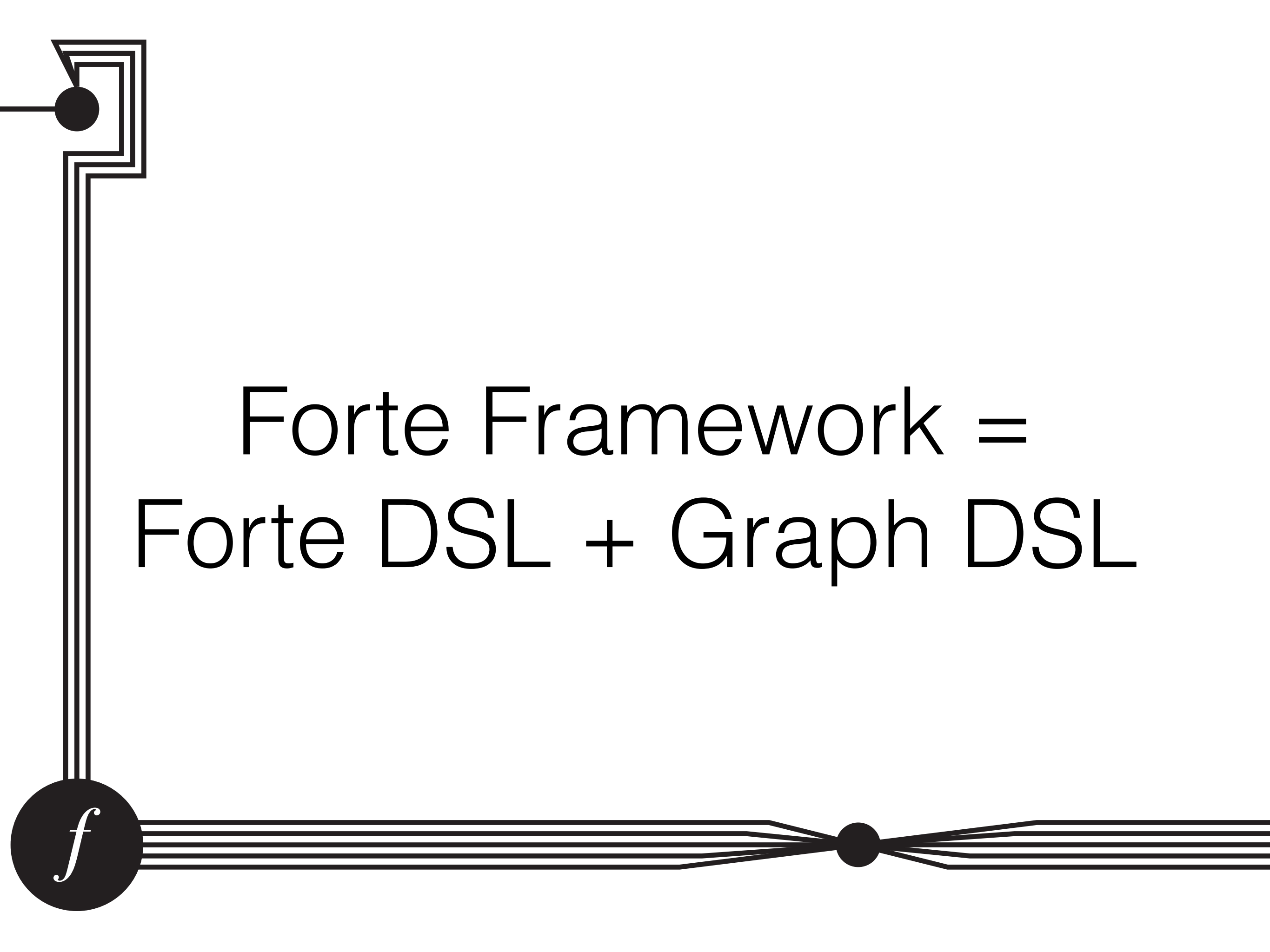
```
=| [5] |= complement . transpose 8
```

```
$>> 1
```

```
$>=: (intersect, transpose 1)
```


Helper Intuitions



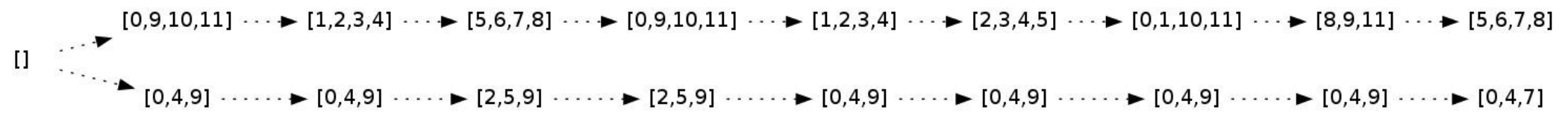


Forte Framework =
Forte DSL + Graph DSL

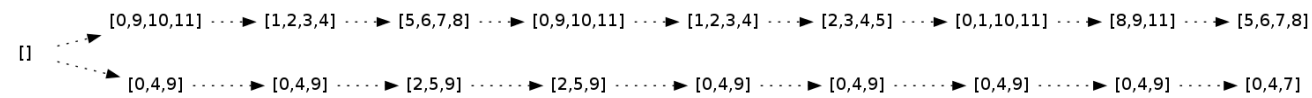
Getting real

```
forte [pcs []] $
  init' <: 2
  +| [1] |+ pcs [0, 9, 10, 11] $+| [2] |+ pcs [0, 4, 9]
  $=| [1] |= t 4
  =| [1] |= t 4 $=| [2] |= t 5
  $=| [1] |= t 4
  =| [1] |= t 4 $=| [2] |= t 7
  $=| [1] |= t 1
  $=| [1] |= t 8
  $=| [1] |= (\\ pcs [10]) . t 10
  =| [1] |= t 9 . (\\/ pcs [10]) $=| [2] |= t 4 . i
```

Final result ...



... and with a little more work



Allegro. (♩ = 144.)
sempre legato

2. *p* *cresc.*

Waveform visualization of the audio, showing amplitude over time.

Thank you!



f